2. Approach and Assessment Scenario

C.T. Kincaid and R.W. Bryce

Generally, the term stochastic describes an approach to anything that is uncertain and is based on probability. Thus, a stochastic analysis is a set of calculations performed using randomly selected values for each uncertain parameter.

The design of the initial assessment performed with the SAC resulted from extensive interactions with Hanford projects, regulators, Tribal Nations, and stakeholders. The approach taken in the assessment follows that advanced by regulatory agencies such as EPA in their guidance on uncertainty analyses (Firestone et al. 1997) and ecological risk assessments (EPA 1998), and DOE in its radioactive waste management manual (DOE 1999a) and implementation guide (DOE 1999b) which support DOE Order 435.1 on radioactive waste management. The System Assessment Capability also was designed with the intent to use it to perform the next composite analysis, an assessment first performed to satisfy Defense Nuclear Facility Safety Board recommendation 94-2.

The approach taken is also consistent with the methods, characteristics, and controls associated with acceptable analyses as described by the Columbia River Comprehensive Impact Assessment (CRCIA) team (DOE/RL 1998a). The approach to the assessment of sitewide or cumulative risk at the Hanford Site prepared by Kincaid et al. (2000) calls for:

- Simulation from 1944 forward.
- Simulation of the subsurface (vadose zone and groundwater) of the Hanford Site and the Columbia River downstream to McNary Dam.
- Inclusion of a suite of risk and impact metrics.
- Continuation of past climate and existing hydroelectric infrastructure.
- Creation of a dual stochastic and deterministic (i.e., single value) simulation capability able to address and resolve uncertainty issues.
- Creation of separable environment and risk/impact assessment components.
- Creation of separable background and Hanford contributions in the Columbia River.

Protecting the Columbia River Corridor is a major focus of Hanford Site cleanup activities.

Simulation From 1944 Forward. Many prior studies of risk and impact (e.g., Wood et al. 1995; Wood et al. 1996, Mann et al. 2001) begin analysis with the waste and barrier system in place at site closure. Those that have addressed future remedial action alternatives (e.g., CH2MHILL 2002) often start with the present day contaminant profile underlying the past waste discharge or disposal facility in question. Because information on the position and levels of contamination in the Hanford vadose zone beneath most waste sites is not available, the SAC initial assessment was designed to begin simulation in 1944 with a clean site and introduce waste discharges and disposals as they were documented to have occurred.

The initial assessment gathers data about Hanford into a suite of models that apply a consistent approach to the analysis of all sites. Results of the assessment will complement site-specific analyses and provide a sitewide context for individual waste site cleanup and closure decisions.

Simulation of the Subsurface Environment and the Columbia River. The initial assessment examines a domain that includes the subsurface from Rattlesnake Mountain to the Columbia River, and the Columbia River from Vernita bridge to McNary Dam. The upper reaches of Dry Creek and Cold Creek drainages on Rattlesnake Mountain and Cold Creek valley define the upper elevations of the unconfined aquifer that underlies the site and discharges into the Columbia River as it passes Hanford to the north and east. Portions of the original Hanford Site that lie north of the Columbia River were remediated and will be transferred to the Hanford Reach National Monument, and are not included in the analysis domain. With regard to the Columbia River, Vernita bridge is located upriver of all Hanford operational areas and represents a logical upstream boundary for analyses. Discharges and background water quality indicative of releases from Priest Rapids Dam can be applied at Vernita bridge and maintain model integrity. Communities near and downstream of the Hanford Site include Richland, Pasco, and Kennewick. In addition, releases from the Hanford Site that adsorb onto river sediment have been identified in the sediment behind McNary Dam. Thus, a primary domain of interest to regulatory agencies, Tribal Nations and stakeholders includes the subsurface environment from Rattlesnake Mountain to the Columbia River, and the Columbia River downstream of Vernita bridge to McNary Dam.

Inclusion of a Suite of Risk and Impact Metrics. The initial assessment addressed the risk/impact to the people, ecology, economy, and cultures of the region. This list of risk and impact metrics is more inclusive than other assessments in an attempt to provide regulators, Tribal Nations, and stakeholders with metrics that address their values to a greater extent than human health alone. In addition to Native American lifestyles, the metrics included address the ecology of the riparian zone and Columbia River, the relationship between water quality and the local and regional economy, and the areal impact to cultures created by groundwater plumes.

Continuation of Climate and Reservoir Infrastructure. The initial assessment assumes that for the next 1,000 years, the future is inconsequentially different from today and basically constitutes present-day conditions. Thus, the current regional and local climate remains unchanged for the 1,000-year period of this analysis. Furthermore, it is assumed that major engineered structures in the region (e.g., the reservoir system on the Columbia River) remain in place. The recorded climate and environmental response (e.g., Columbia River stage and discharge records) since startup of site operations were used to simulate the period from 1944 to present. The climate record from 1961 to 1990 was used to represent the future climate. Consequently, the Hanford Site remains a semi-arid shrub-steppe environment in the simulations. The riparian zone, Columbia River, and the river's ecosystem is assumed to remain essentially unchanged for 1,000 years. Also, human populations, economic conditions, and cultures will be unchanged and based on the current socio-economic setting. Analyses of alternate future climates (e.g., climate change and glacial flooding) and potential future events (e.g., failure or removal of the reservoir system) are deferred to a later time.

A major assumption of the initial assessment is that the current regional and local climates remain unchanged and engineering structures (e.g., Grand Coulee Dam) will be in place for the long term.

Creation of a Dual Stochastic and Deterministic Capability. The SAC is designed to provide a stochastic simulation capability able to quantify uncertainty through a Monte Carlo analysis. However, an option exists to perform a deterministic simulation. Because of the number of waste sites and contaminants, the computational resources required to perform an analysis, especially a stochastic analysis, are significant. Therefore, the initial assessment has been limited to 25 realizations and the objective is to gain insight regarding the central tendency and spread in the results for the case being analyzed.

Separable Environment and Risk/Impact Simulations. Key to the approach of SAC simulation was the assumed separability of environmental contaminant distribution and risk/impact metrics. Results of contaminant migration and fate within the environment were stored for the entire simulation space and time. Then, risk/impact analyses were performed using the stored concentration results. Thus, multiple points of exposure and multiple exposure scenarios can be simulated and analyzed without recalculating the release and environmental transport. If animals were to intrude into waste, they could act as transport vectors and might require a feedback loop from risk receptor to environment contamination levels. However, the initial assessment assumed that DOE completes cleanup and remedial actions, including the placement of covers and barriers to defeat inadvertent intrusion by people and animals.

Separable Background and Hanford Contributions. The analysis of background and non-Hanford contributions to contamination and risk were modeled only in the Columbia River. These contributions to the analysis were introduced in the quality of water entering the analysis from Priest Rapids Dam, and the Yakima, Snake, and Walla Walla Rivers. Simulations were run with only the background and non-Hanford contributions and a second time with Hanford Site contributions superimposed on the background and non-Hanford contributions. Background contributions from the Hanford Site (e.g., in the soil or groundwater) are neglected in the initial assessment because of the relatively small contribution the Hanford Site background makes to the Columbia River considering the upstream drainage. The Hanford Site groundwater contribution is approximately 1.1 cubic meters (40 cubic feet) per second compared to the Columbia River flow in the Hanford Reach of 3,400 cubic meters (120,000 cubic feet) per second. In addition, background contributions are included for the Columbia River because of the role they play in the ecological system. By simulating background and Hanford Site contributions plus background, analysts were able to evaluate and present the difference between the two results.

Background contributions to the Columbia River in comparison to Hanford contributions are potentially significant. Several changes to the Columbia River have occurred in the same time frame as Hanford Site operation. The region, including Canada, has developed a mining and industrial base that contributes waste water to the river. Many of the radionuclides evaluated in the initial assessment are also widespread in the surface environment of the world due to accumulated fallout from above-ground nuclear weapons tests conducted in the mid twentieth century. These non-Hanford, manmade radionuclides contribute background risks that must be considered when evaluating the risks posed by Hanford contaminants. In addition to Hanford, these changes and others (e.g., agriculture and reservoir operation) have influenced and changed the river since 1940. Risks posed by Hanford Site releases should be viewed in terms of the Hanford Site increment over background levels of the region. The approach described above in designing the SAC initial assessment enables such an analysis.

Looking toward the 300 Area of the Hanford Site where research has been conducted and reactor fuel fabricated.

The Assessment Scenario Analyzed – Hanford Site Disposition Baseline. Part II of CRCIA (DOE/RL 1998a) states that an assessment "…is to be performed maintaining as much consistency as possible with each set of Hanford Sitewide cleanup/disposal decisions and with each subsequent revision. In other words, for the collection of DOE documents which, at any given time, constitutes the approved Hanford Site post-cleanup end state, there will be a corresponding … assessment of resultant impact." Further, Part II notes that "…if no officially recognized end-state plan exists for the overall Hanford Site, the … analysts will develop with DOE's recommendations, the most credible surrogate end-state information available." This essentially calls for a Hanford Site Disposition Baseline assessment to be consistent with the current definition of the Hanford Site as cleanup proceeds and after all cleanup and waste disposal actions are complete. While Part II of the CRCIA document defined what a Hanford Site Disposition Baseline assessment should be, it did not enumerate the specific cleanup and disposal actions. This section provides a summary of the Hanford Site Disposition Baseline.

Hanford Site Disposition Baseline

The Hanford Site Disposition Baseline is a description of the disposal and remedial actions that will occur as the Hanford Site moves toward closure. It represents the most credible end-state information available from the U.S. Department of Energy in its multiyear plans, and is consistent with estimated lifecycle costs of Hanford Site cleanup and closure.

DOE is required in its multiyear plans to provide an estimated lifecycle cost for Hanford Site cleanup and closure. These costs are a function of an assumed baseline end state for the Hanford Site. The end state for the site is the combination of end states for each individual cleanup project, facility, or disposal, for the entire Hanford Site. This collection of end-state assumptions represents the Hanford Site Disposition Baseline. The multiyear work plans from fiscal year 2000 were the primary source of end-state assumptions. However, to ensure consistency across multiple programs, additional insights with regard to the long-term strategy for cleanup and closure of the Hanford Site were drawn from other documents, including the following:

- *Hanford Strategic Plan* (DOE/RL 1996a).
- Environmental impact statements (EIS), environmental assessments, and records of decision.
- *Hanford Site Environmental Management Specification* (DOE/RL 1999a).
- *Technical Issues Management List* (FDH 2000).
- Path-to-Closure (DOE/RL1998a; DOE/RL 1998b).

The multiyear work plans and these additional sources provide a set of assumptions regarding the disposal locations, remedial actions, recovery and treatment efficiencies that define the end state of the Hanford Site.

The *Final Hanford Comprehensive Land Use Plan Environmental Impact Statement* (DOE 1999c) presents a preferred alternative for land use for the

As the Hanford Site approaches closure, the largest segments of the Columbia River corridor will be preserved to protect cultural and ecological resources.

entire Hanford Site. However, while this environmental impact statement has considered the stated values of the public, it focuses on DOE's role as caretaker for only the next 50 years. Accordingly, the land uses identified do not translate into remedial actions or cleanup standards. For example, the environmental impact statement indicates the river corridor will not be devoted to residential land use. Rather, the river corridor will be devoted to a combination of recreation and preservation. However, the environmental impact statement does not define the remedial actions or cleanup levels consistent with recreation and preservation land use. The environmental impact statement indicates the Central Plateau land use will be industrial and waste management, but does not define the level of cleanup required at individual waste sites to provide an industrial setting (i.e., whether waste needs to be removed from the upper 4.5 meters [15 feet]). Consequently, the Hanford Site Disposition Baseline does not rely on the *Final Hanford Comprehensive Land Use Plan* to define remedial actions.

The 100 Areas. As indicated in the *Final Hanford Comprehensive Land Use Plan Environmental Impact Statement* (DOE 1999c), as the Hanford Site approaches closure, segments of the Columbia River corridor would be devoted to high- or low-intensity recreation, but the largest portion would be designated preservation to protect cultural and ecological resources. The corridor included the river islands and a quarter-mile buffer zone.

The planned remedial action for the 100 Areas are designed to permit residential occupancy when complete. The initial assessment included remedial actions in the models that moved waste from CERCLA remediation sites to the Environment Restoration Disposal Facility on the Central Plateau.

Waste within the 100 Areas includes spent fuel in the K Basins; surplus facilities, including the graphite cores of the production reactors; miscellaneous underground storage tanks; liquid discharge sites; and solid waste burial grounds. In addition, there were discharges directly to the Columbia River from cooling water retention basins, and there are contaminant plumes in the groundwater underlying the 100 Areas because of liquid discharges and unplanned releases. In general, the planned remedial actions for the 100 Areas are designed to permit residential occupancy when complete.

The following remedial actions were included in the initial assessment. The spent fuel and sludge will be removed from the 100 Areas, stabilized, and packaged for eventual disposal off site in national repositories. Surplus facilities will be removed from the 100 Areas, except the B Reactor that has been declared a national historic monument. Contaminated soil from liquid discharge sites will be removed to a depth of 4.5 meters (15 feet) below grade, and all solid waste will be removed. Except for the graphite cores that will have their own disposal trench, debris from surplus facilities, soil from liquid discharge sites, and solid waste will be disposed in the Environmental Restoration Disposal Facility trench on the Central Plateau.

Additional detail on the disposal and remediation actions included in the SAC initial assessment were listed in Kincaid et al. (2000).

The 300 Area will be cleaned up to a standard that allows future industrial use.

The 300/400/600 Areas. In general, the *Final Hanford Comprehensive Land Use Plan Environmental Impact Statement* (DOE 1999c) indicated that the planned remedial actions for the 300, 400, and 600 Areas should permit continued use of a portion of the site, including industrial use of the 300 Area, 400 Area, and Energy Northwest's site. Segments of the Columbia River corridor would be devoted to high- or low-intensity recreation, but the largest portion would be designated for preservation to protect cultural and ecological resources. Lands west of State Highway 240 to Vernita Bridge, including the Arid Lands Ecology Reserve, the McGee Ranch and Umtanum Ridge, and lands north of the Columbia River, will be designated for preservation. Land use for the remainder of the 600 Area would be designed for conservation to support a possible Bureau of Land Management mission for multiple users, including mining of aggregate.

Waste within the 300, 400 and 600 Areas is similar to that in the 100 Areas, and includes some spent fuel and nuclear material, surplus contaminated facilities, liquid discharge sites, and solid waste burial grounds such as 618-10 and 618-11. Spent fuel within these areas is the residual of research programs dealing with fuel and spent fuel disposal. It includes assemblies, fuel pins, and/or pieces of fuel from commercial light-water reactors, various test reactors, and the Fast Flux Test Facility. They are in interim storage in the 300 and 400 Areas until storage is available in the 200 Area. Other spent nuclear materials include uranium that is in interim storage, nuclear materials including some tank waste, the inventory of unirradiated uranium, and a few stored cesium-137 and strontium-90 capsules and isotopic heat sources. All nonessential, surplus buildings and facilities without a post-cleanup use will be removed. However, explicit inventories for individual surplus buildings or facilities (including the Plutonium Recycle Test Reactor and the Fast Flux Test Facility reactors) are not included in the current analysis. The forecasts of future amounts of solid waste include the decommissioning and decontamination debris associated with cleanup of all facilities prior to their transition to the environmental restoration contractor for final remedial action, assuming the waste meets waste acceptance criteria for disposal.

Waste from the future decommissioning of Energy Northwest's Columbia Generating Station is included in disposal forecasts for the commercial low-level waste site operated by U.S. Ecology, Inc.; however, the inventory is uncertain and will be refined in future analyses.

Remedial actions to be undertaken for 300/400/600 Area sites and included in the assessment are similar to those of the 100 Areas. All liquid discharge sites and solid waste burial grounds associated with the 300 Area will be excavated to 4.5 meters (15 feet) and all solid waste will be removed. The 300 Area lands will be cleaned up to a standard that allows future industrial use rather than residential occupancy. Debris from Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) remedial actions from these areas will be disposed in the Environmental Restoration Disposal Facility on the Central Plateau. Waste from the future decommissioning of Energy Northwest's Columbia Generating Station is included in disposal forecasts for the commercial low-level waste site operated by U.S. Ecology, Inc.; however, the inventory is uncertain and will be refined in future analyses. The burial grounds 618-10 and 618-11 will be excavated and all solid waste removed. The initial assessment does not include a tritium inventory in these waste sites because none is indicated in the records. Additional research is planned to identify the source of tritium in groundwater beneath these sites. The baseline disposition of specific 300, 400, and 600 Area waste is listed in Kincaid et al. (2000).

Central Plateau. Waste within the Central Plateau includes spent nuclear fuel; other spent nuclear materials, including Plutonium Finishing Plant material and cesium-137 and strontium-90 capsules; surplus facilities, including canyons and tunnels; single- and double-shell tank waste; liquid discharge sites; unplanned release sites; and solid waste burial grounds. The Central Plateau includes the 200 West and 200 East Areas, the commercial low-level waste disposal facility operated by U.S. Ecology, the Environmental Restoration Disposal Facility, and the BC cribs and trenches that are located south of the 200 East Area and east of the U.S. Ecology commercial low-level waste site (Figure 2.1). Virtually all of the radioactive and chemical waste generated during Hanford Site operations that will remain on site will be disposed within the Central Plateau. The *Final Hanford Comprehensive Land Use Plan* (DOE 1999c) indicates that future land use will be limited to a combination of industry and waste management activities.

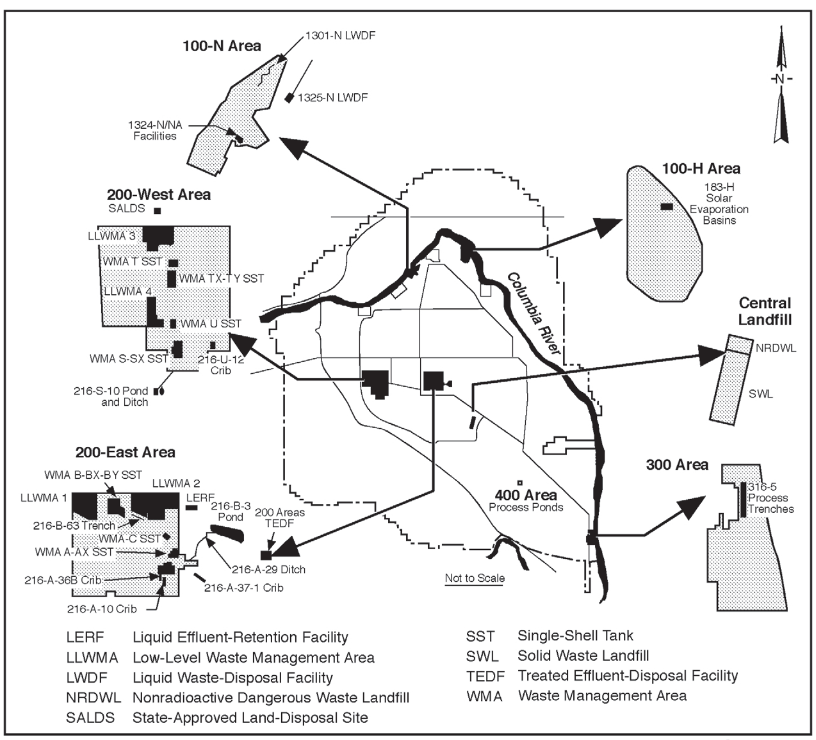

Figure 2.1. *RCRA waste units on the Hanford Site.*

The waste removal and remedial action scenario in the initial assessment has spent fuel, special nuclear materials, immobilized high-level waste, and transuranic waste transported offsite before site closure. Ninety-nine percent of the tank waste will be retrieved, separated into high-level and low-activity fractions, and solidified. The low-activity fraction is disposed of onsite, and the high-level fraction is disposed of offsite at a national repository. Low-level radioactive waste from these activities is also disposed onsite. The assessment assumes 30,280 liters (8,000 gallons) of fluid are lost from each single-shell tank during waste retrieval. Remedial actions for past tank leaks, future tank losses, and tank waste residuals will be limited to in-place stabilization and the placement of surface barriers. It is assumed that similar remedial actions will be taken for all liquid discharge sites, unplanned release sites, and solid waste burial grounds within the Central Plateau.

Virtually all radioactive and chemical waste generated during Hanford operations, that will remain on the site, will be disposed on the Central Plateau.

The predominant barrier selected for application at Hanford is the Modified RCRA Subtitle C Barrier (DOE/RL 1996b). This barrier includes an underlying asphalt layer that ensures a low infiltration rate during the barrier operational life. An infiltration rate of 0.1 millimeters (0.0039 inch) per year is applied for the first 500 years. After 500 years, the cover performance is assumed to degrade to natural conditions. However, natural conditions vary with the major soil types found in the operational areas. Therefore, within the 200 Areas the natural infiltration varies from 0.9 millimeters (0.0355 inch) per year in southern 200 East Area to 4.0 millimeters (0.1576 inch) per year in the 200 West Area.

All nonessential surplus buildings and facilities without a post-cleanup use will undergo decontamination and decommissioning. These will include all canyon buildings and the Plutonium Finishing Plant. Debris from those that can be removed will be disposed in the Environmental Restoration Disposal Facility. The Environmental Restoration Disposal Facility, and the trench that receives the graphite cores of the production reactors, will receive a protective surface barrier when closed. Other facilities, including the canyon buildings and plutonium-uranium extraction building tunnels, will be stabilized in place and covered with a protective surface barrier. For the purposes of the initial assessment, it is assumed that groundwater contaminant plumes beneath the Hanford Site will not be subjected to remedial action. This assumption is made for the initial assessment to avoid the introduction of complex logic that would initiate and terminate pump-and-treat actions. Additional detail on the disposal and remedial actions for the Central Plateau included in the initial assessment are listed in Kincaid et al. (2000).